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THE MEASUREMENT OF SCATTER AND ABSORPTION
USING THREE SPECTROPHOTOMETRIC TECHNIQUES

by

Christopher H. Pearson

A thesis submitted in partial fulfillment
of the requirements for the degree of
Bachelor of Science in the School of
Photographic Arts and Sciences in the
College of Graphic Arts and Photography
of the Rochester Institute of Technology

Date of Thesis Examination
26 April 1985

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Submitted to the
Imaging and Photographic Science Division
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ABSTRACT

Three methods for scattering and absorption measurements were compared for correlation; Kubelka-Munk, 4pi and an in transmission compartment scattering measurement method. The results indicated highest correlation between the 4pi and Kubelka-Munk absorption measurements. The 4pi and Kubelka-Munk scattering measurements had the highest correlation for scattering, and almost no correlation was found between Kubelka-Munk and in transmission compartment scattering measurements.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to his thesis advisor, Mr. C. Mickey McCarthy of the Milton Roy Company, formally Bausch and Lomb, for his kindness, patience and guidance throughout the period of this thesis.

Special thanks to Dr. Franc Grum and R. Mitchell Miller for their advice and assistance with measurements and software. Also thanks to RIT and the Munsell Color Science Laboratory for the use of equipment.

Finally, the author wishes to acknowledge Dr. Ronald Francis for his enthusiasm in his students and the field of Imaging Science.

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I. INTRODUCTION

Sir Isaac Newton was one of the earliest personalities in the color science field to introduce the circular arrangement of hues.[1] This led to later attempts by people such as Johann Wolfgang von Goethe and Phillip Otto Runge to logically arrange colors. Albert H. Munsell, Wilhelm Ostwald and others created color order systems based on visual responses. Then John Guild and William David Wright collected visual data to try and spectrally characterize human vision. With this data, the principles of today's modern color specifications were constructed; specifications that could be standardized and repeated accurately with proper instrumentation. The CIE is one of the main standards organizations for color measurement and, with their recommendations, spectrophotometric standards were adopted for the measurement and calculations of color[2]. These standard color metrics allowed universal measurement and specification of color. The problem was that there were several ways to obtain the spectral data necessary to describe color in CIE terms; from different measurement geometries, to including or excluding the specular component of the reflected or transmitted radiation. It is at this point that others step in and describe standard methods for the measurement of specific types of materials that best

characterize them[3]. As new materials are invented, and new uses for old ones are devised; as manufacturing becomes more advanced, and tolerances become more exacting, measurement methods have to be reviewed and revised. Since most of the colorimetric calculations are based on spectral data of some sort, the concern is to make the best spectrophotometric measurement possible in the shortest time and in the most economical fashion.

The driving force behind all scattering and absorption measurements is color formulation. This is the technique of calculating the correct amount of primaries that need to be mixed together in whatever fashion to match a specified color. In the past the best way to characterize the primaries has been through the use of absorption and scatter. In the case of turbid media, the measurements have not been reliable for accurate formulation. This research will not look at color formulation, but rather the component measurements of absorption and scatter. It will concern itself with the problems in the area of solid-turbid media measurements in materials such as plastics. The requirement of any method of measurement and calculations is that it should reproduce what is already known to work. In this case, the Kubelka-Munk method works for samples that are of low to medium turbidity, and are optically thick. Thus this

research will attempt to describe other simple methods that might also work with the same or better accuracy than Kubelka-Munk.

Quantities used to describe the optical properties of solid media are absorption and scatter. Absorption is that quantity of radiation that a sample does not return when illuminated, and scattering is that radiation that is returned, deviated in its path through or off of a sample. The most widely used method for measuring and calculating scatter and absorption is one outlined by Kubelka and Munk in 1931[4] using reflectance measurements over a black and white substrate. This method, combined with surface corrections as outlined by Saunderson[5] comprise the most commonly used method for calculating scatter and absorption. Because it is so widely used it will not be discussed in great detail here. Those wishing more information about the Kubelka-Munk equations are directed to reference [6]. Although the equations are widely used, they are not without limitations. The calculations assume that the flux striking the sample and the flux in the sample is diffuse. If the former assumption is true, then the measurement cannot be made diffusely, that is there is no spectrophotometer that can illuminate and collect diffusely. The latter assumption only occurs when the sample is thick enough to scatter all

of the internal flux. Even though the calculations have these and other drawbacks, they have been extensively used in color formulation.

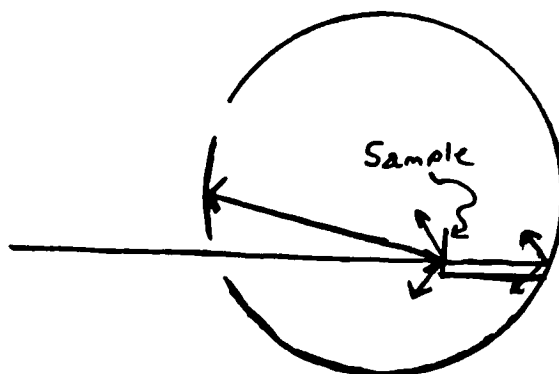
There has been much written on the measurement of absorption and scatter using many-flux theories[7]. These theories are either to calculation intensive or require non-standard instrumentation and therefore will not be investigated. The goal of the research is to investigate alternate methods of measuring scatter and absorption with minimum complexity.

A second method of absorption measurement was outlined by Grum using a 4pi geometry[8] and was said to be superior to the Kubelka Munk method because it measured absorption directly. This method was adapted, to also measure scattering directly. The 4pi geometry requires that the sample be placed within the integrating sphere of a spectrophotometer and that the illumination on the sample be regular. With the sample in the sphere it is illuminated with a narrow beam, and radiation is collected at all angles. This is then compared to the the reference beam with no sample and the absorption is the ratio subtracted from unity (see figure 1). To measure scatter, the holder is backed with black to trap out any regular reflection, and the specular port is opened to trap any regular reflection

(see figure 2), thus any radiation reaching the detector will have been scattered by the sample.

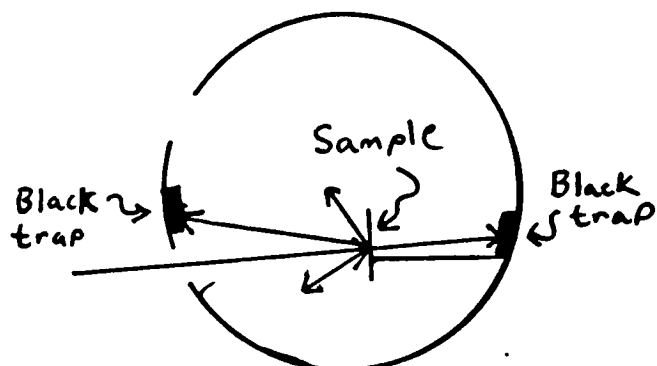
The third and last method places the sample at various positions in the transmission compartment and measures the scatter over different solid angles (see figure 3). The sample port in this case has a black trap to trap out any regular transmission, thus measuring only radiation scattered into the sphere.

The latter two methods will be compared to the first for correlation. The methods are not put forth as a replacement for the Kubelka Munk equations, but rather as an alternate one measurement approach that may work in certain regions of absorption and scatter.



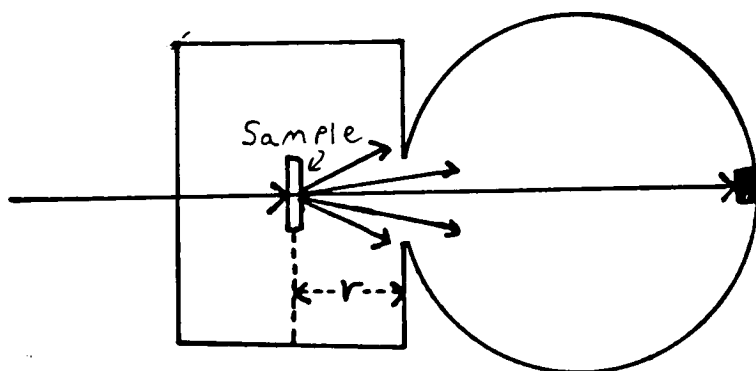
4pi absorption

Figure 1



4pi scatter

Figure 2



Transmission compartment scattering measurement

Figure 3

II. EXPERIMENTAL

A. Samples

Before any comparisons could be made, samples were required to measure. Grum suggested the use of film samples and some were prepared. They were prepared using Kodak film type Plus-X pan professional 4" X 5". It was exposed in a Kodak model 101 sensitometer with a large 5-step step tablet with differing amounts of neutral density to vary the exposure. The film was then processed in an R.I.T. olive jar processor for 3 min. using developer D-76.

The film samples while ranging from 0.31 to 1.86 density units did not have a sufficient range of scattering or absorption, so plastic samples were also used. They were of various unknown turbidity, and the samples used for the comparison were chosen to have a wide range of Kubelka Munk scattering coefficients. The samples were all non-selective and non-fluorescing.

B. Generic Programming

While each technique required programming to arrive at the final value for absorptance and scattering, there were some generic routines that had to be written for data collection, storage and retrieval. All of the measurements made during this research were done so using a Diano Match Scan II spectrophotometer which the author interfaced into a DEC Rainbow 100 microcomputer for data

acquisition and storage. The subroutines for the Rainbow were all written in compiled GW-BASIC and can be found in appendix A. A subroutine was written that would collect data from the Match Scan. The interface required was simply one that would send a request for a scan out of the communications port of the Rainbow into the terminal port of the Match Scan, and to collect the data as it came out and store it in the Rainbow. Other routines were written to save data onto disk, retrieve data from disk, get a legal filename, and to get a string of fixed length.

Other programming was done to plot data on a Hewlett-Packard 7475A digital plotter using routines provided by R. Mitchell Miller and modified by the author for these data. These subroutines were written in Oregon Software Pascal-2 running in the Munsell Color Science Laboratory's DEC LSI-11/73 timesharing system under the TSX-Plus operating system.

C. Kubelka-Munk

To calculate Kubelka-Munk scattering and absorption, the author used the incomplete hiding case. To accomplish this the samples had to be measured over a black and white

of known reflectance. The first quantity to find is Kubelka-Munk a , and is calculated as follows:

$$a = \frac{(R - R_g) * (1 + R_0 * R_b) - (R_0 - R_b) * (1 + R * R_g)}{(R - R_g) * (R_b + R_0) - (R_0 - R_b) * (R_g + R)}$$

Where:

a = Kubelka-Munk a
 R = Reflectance over white
 R_g = Reflectance of the white
 R_0 = Reflectance over black
 R_b = Reflectance of the black

The next step is to calculate Kubelka-Munk b as follows:

$$b = (a^2 - 1)^{1/2}$$

Where:

a = Kubelka-Munk a
 b = Kubelka-Munk b

With Kubelka-Munk a and b calculated, the scattering coefficient can be calculated as follows:

$$S = \frac{1}{b} \left| \coth^{-1} \frac{a - R}{b} - \coth^{-1} \frac{a - R_g}{b} \right|$$

Where:

S = Kubelka-Munk scattering coefficient
 b = Kubelka-Munk b
 R = Reflectance over white
 R_g = Reflectance of white

From the scattering coefficient, the absorption coefficient can be calculated as follows:

$$K = (a - 1) * S$$

Where:

K = Kubelka-Munk absorption coefficient

a = Kubelka-Munk a

S = Kubelka-Munk scattering coefficient

All of the above measurements and calculations were done after Saunderson[5] corrections were made, and are implemented in the subroutine in appendix B. The routines are used in conjunction with the data acquisition, storage and retrieval subroutines, in the development of a fully integrated Kubelka-Munk K and S measurement software package called KMSCAN.

The white background used was the instrument standard for the Match Scan. This white was Russian Opal glass that was calibrated at the Bausch and Lomb corporation and is traceable to the National Bureau of Standards. The black background used was a black glass also supplied with the Match Scan II. All of the measurements made were done with the specular included, and the calibration was done internal to the Match Scan. To use the system, the Match Scan must be calibrated before running KMSCAN. The calibration was performed as per the instructions for the Match Scan II for a wavelength range from 380nm to 700nm every 10nm with the specular included.

Once the instrument was calibrated the program was

run. It allows for all of the input to come from either the instrument or a disk file. It first asks for the reflectance of the white background, which can then be either scanned or retrieved from a disk file. After the white comes the black, followed by the sample over white, and the sample over black. After all of the measurements are made, or the files are retrieved, the program then calculates the K and S for the sample at each wavelength. Next the software asks where the operator wants the spectral scattering data stored, followed by where the operator wants the spectral absorbance data stored. The program then allows the operator to use the same numbers for the backgrounds and make more measurements over white and black, or to remeasure the white and black backgrounds and continue, or exit the program.

D. 4pi

The next measurement investigated was using the 4pi method for measuring scatter and absorption. To accomplish the 4pi geometry, a fixture was used to hold the sample in the integrating sphere (see figure 4). It was made from 1.5mm diameter copper tubing formed into a ring and soldered to another piece of tubing. This part was then soldered through a plate and the entire fixture was painted with BaSO₄ paint. This caused the back plate to become a part of the sphere wall at the reflection port. The tubing was used

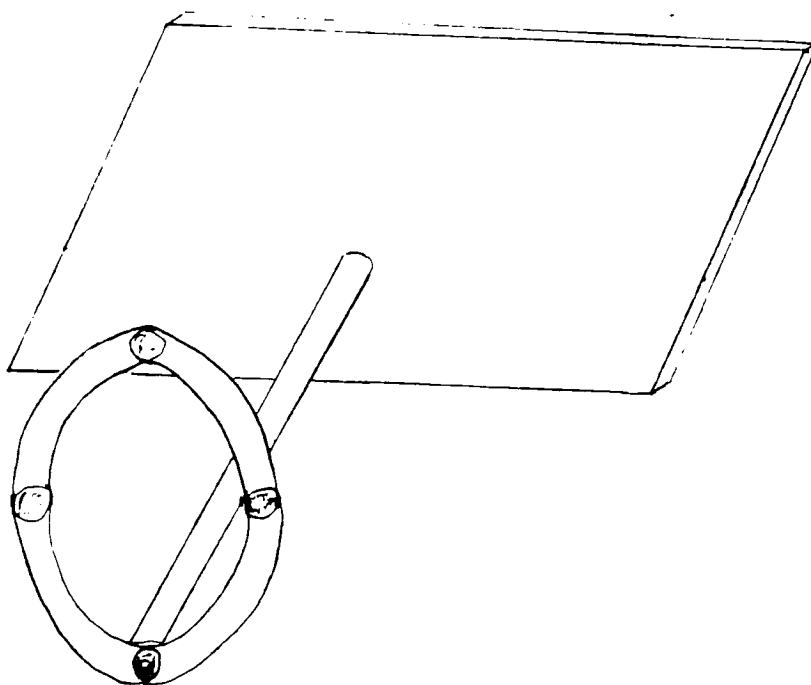


Figure 4 : 4pi sample holder

in conjunction with a vacuum to hold the sample on the ring. The vacuum was not strong enough to hold the plastic samples, so a ring of white double stick tape was used to attach the samples to the fixture. The fixture was already built at the Eastman Kodak Research laboratories and was the one used in the research in reference[7].

The technique used to measure absorptance was essentially the one used by Grum[7], but the scattering measurements presented some interesting problems. The technique employed was developed is essentially the same as the absorptance measurement except in calibration. Because the quantity desired was scatter, all of the regular flux must be omitted from the measurement. To this end, black felt the size of the beam was placed directly in the beam on the back plate of the fixture. Also the specular port was set to trap out the specular reflectance. To set up the system, a front surface mirror was placed on the sample holder, in the integrating sphere. The beam was then reduced to 1mm and the fixture was adjusted such that the beam went directly through the circle and the reflection went through the specular port. This assured that the sample was being correctly illuminated, and that the specular component was really removed. The next step was to find the placement of the black felt such that it only trapped the specular beam and left the surrounding area white. In the Match Scan II, the transmission compartment holds the specular slide; this

slide has three positions, one places white over the specular port to include the specular, another places black to exclude the specular, and the third opens the port into the compartment and has a mirror for viewing into the sphere. Using this third position, the beam size was able to be reduced, the collecting of the specular from the holder was adjusted, and the black felt was able to be placed in the correct position.

Software was then written to make the measurements, and calculate both the absorption and scatter. The software requires that the specular slide be moved from the included position to the excluded position. It was discovered that when the slide is moved, the Match Scan II changes the voltage to the detector thus changing any calibration. Therefore, a beam balance in the instrument was not possible. Also, since the specular was being excluded, a known sample needed to be calibrated to at both positions of the specular slide. Circular glass cover slides were used to do the calibration because it should have zero scattering, and the amount of the specular reflection can be calculated using the Fresnel equation.[9]

Before the amount of front surface reflection can be calculated, the index of refraction must be determined. The method employed here was to find Brewster's angle[10]. Brewster's angle is that angle of incidence to the normal when the reflected radiation is completely polarized. Once

this angle is determined, the relationship to the index of refraction is as follows:

$$\tan(a) = \frac{n_i}{n_t}$$

Where:

- a = Brewster's angle
- n_i = the index of refraction in the first medium (air, assumed to be 1.0)
- n_t = the index of refraction of the reflecting medium

With the index of refraction, the amount of regular reflectance can be calculated as follows:

$$R = \left| \frac{n_t - n_i}{n_t + n_i} \right|^2$$

Where:

- R = the specular reflectance
- n_i = the index of refraction in the first medium (air, assumed to be 1.0)
- n_t = the index of refraction of the reflecting medium

Before the index of refraction can be calculated, Brewster's angle must be determined. This angle was measured using the Munsell Color Science Laboratory Goniospectrophotometer.

Brewster's angle was found by rotating the sample until the signal was minimized. Although Brewster's angle changes over wavelength, the differences were such that the calculations were not sensitive to them. Therefore 560nm was chosen as a midrange wavelength.

Other information needed to calibrate the 4π measurements was the transmittance of the glass. This was measured using the Munsell Color Science Laboratory's Diano-Hardy double beam spectrophotometer. For the specular included calibration, the fresnel reflection was added onto the value of transmittance.

This data was then used for the calibration for measuring 4π scatter and absorptance. Using some of the routines written for KMSCAN, MATCH was written to calibrate and measure 4π quantities. The software (see appendix C) first asks the operator to mount the glass and set the specular slide to the included position. This then calibrates the measurement for specular included. Next the operator is asked to move the slide to the excluded position and calibration for that is performed. The software retrieves the data calculated for the glass, and calculates a multiplicative correction factor for each wavelength. Thus, every measurement afterwards is multiplied by the correction factor to attain the true value. The glass is then removed, the sample mounted with the black felt on the plate, and scatter is measured. The numbers have an absolute range from 0 - 100, and are a quantity like spectral transmission. The black felt is then removed from the plate, the slide moved to the included position, and absorptance is then measured. The quantity coming from the instrument represents all of the radiation that is not absorbed by the

sample, thus to find the absorptance, the value is subtracted from 100 percent. The software then stores the data on diskette and asks the operator if he wants to make another measurement without recalibrating. Each sample was then measured and the data stored.

E. Transmission compartment scattering

The last method of measuring scatter is accomplished in the transmission compartment. The measurement is a transmission measurement with a certain solid angle of acceptance. The size of the angle depends on and can be calculated from the distance of the sample to the transmission port, and the size of the port. The angle can be calculated as follows:

$$s = \frac{A}{r^2}$$

Where:

s = the solid angle in steradians
 A = the area of the transmission port
 r = the distance from the sample to the transmission port

Then the solid angle excluded by the black is calculated and subtracted from the entire acceptance region. The measurement was made using a program called TSCAN (see appendix D.). The Match Scan II was first calibrated to the 100% line and then the program run. The program is merely a

data collection and storage routine that asks the operator to mount the sample and then measures it. The data can then be stored on disk.

The measurement was done on all samples for two solid angles, 0.24 steradians, and 3.80 steradians.

III. RESULTS

The Match Scan II was able to repeat measurements of reflection +/- 0.004 using a scale from 0 to 1. On repeat measurements using the Kubelka-Munk software, K could be measured +/- 0.1 and S +/- 0.1. The 4pi measurement was reproducible to 0.007 using a scale from 0 to 1.

The data collected for each method was compared en' masse, that is all of the wavelengths were included in the comparison for each method against another. Because the numbers were from totally different data sets, the only information easily attainable would be basic trends in the data. Each method's data was compared by calculating a correlation coefficient for the entire data set. The calculation went as follows[10]:

$$r = \frac{S_{xy}}{(S_{xx}S_{yy})^{1/2}}$$

Where:

r = the sample correlation coefficient

$$S_{xx} = \sum_{i=1}^n x_i^2 - \frac{1}{n} \left(\sum_{i=1}^n x_i \right)^2$$

$$S_{yy} = \sum_{i=1}^n y_i^2 - \frac{1}{n} \left(\sum_{i=1}^n y_i \right)^2$$

$$S_{xy} = \sum_{i=1}^n x_i y_i - \frac{1}{n} \left(\sum_{i=1}^n x_i \right) \left(\sum_{i=1}^n y_i \right)$$

Table 1 shows the correlation coefficients between each of the methods. Figures 5 through 11 are plots of the data between each method.

KM vs 4pi scatter.....	r = 0.77
KM vs 4pi absorbtion.....	r = 0.94
KM vs 0.24 steradian scatter.....	r = -0.43
KM vs 3.80 steradian scatter.....	r = -0.20
0.24 steradian vs 4pi scatter	r = -0.11
3.80 steradian vs 4pi scatter.....	r = 0.27
0.24 steradian vs 3.80 steradian scatter...	r = 0.91

Table 1.
Correlation coefficients between each treatment

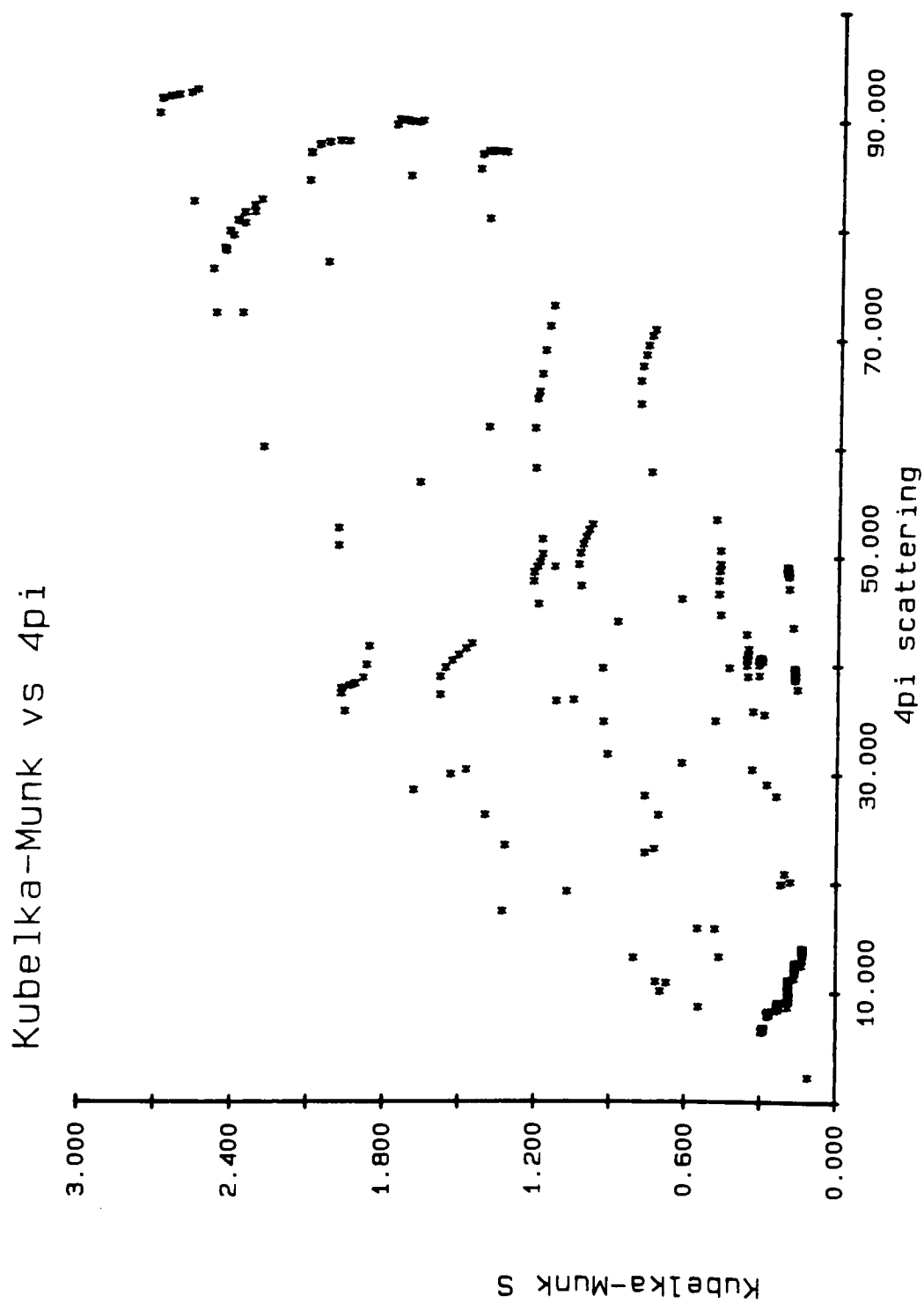


Figure 5

Kubelka-Munk vs 4pi

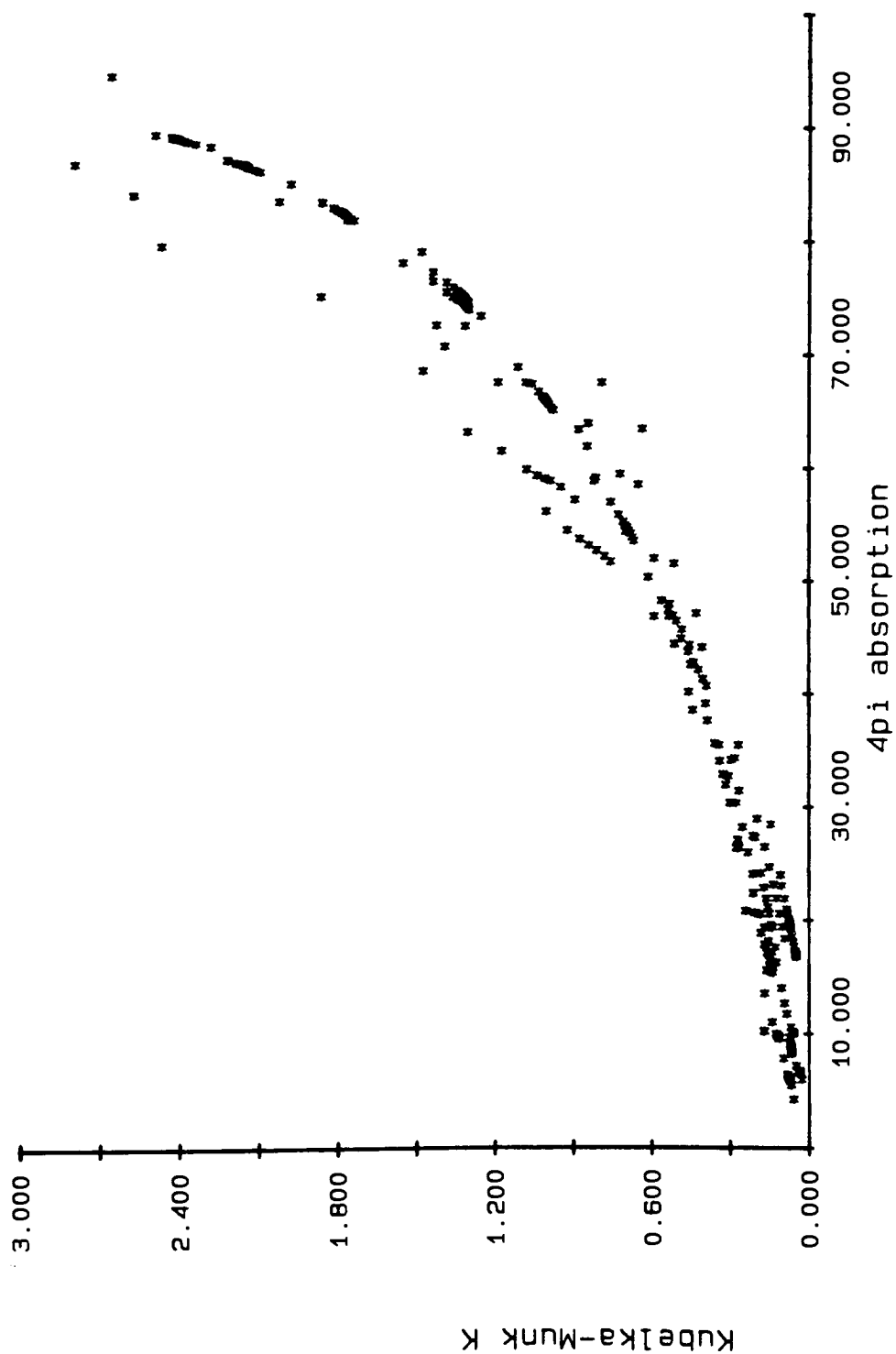


Figure 6

Kubelka-Munk vs 0.24 steradian scatter

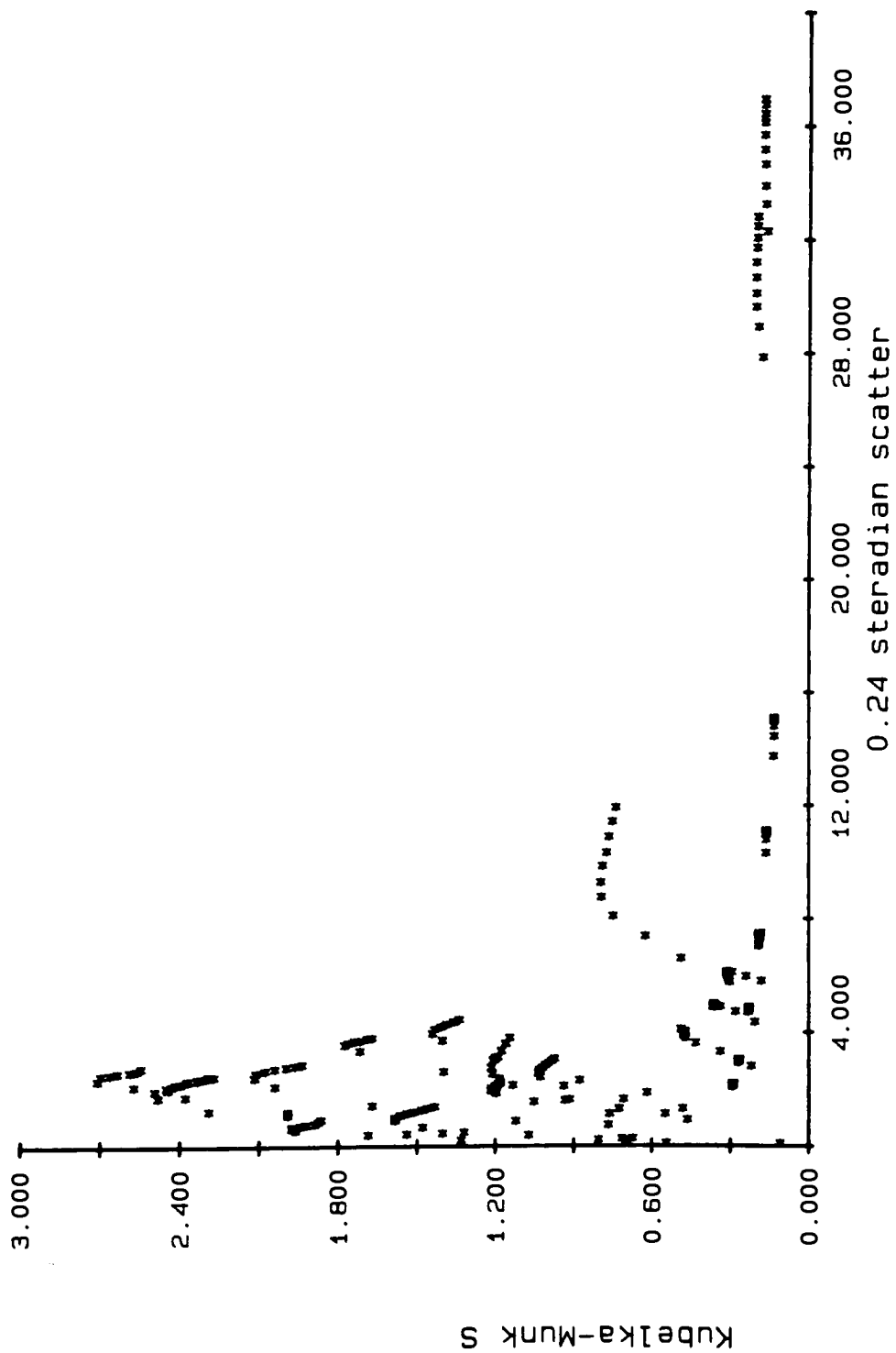


Figure 7

Kubelka-Munk vs 3.80 steradian scatter

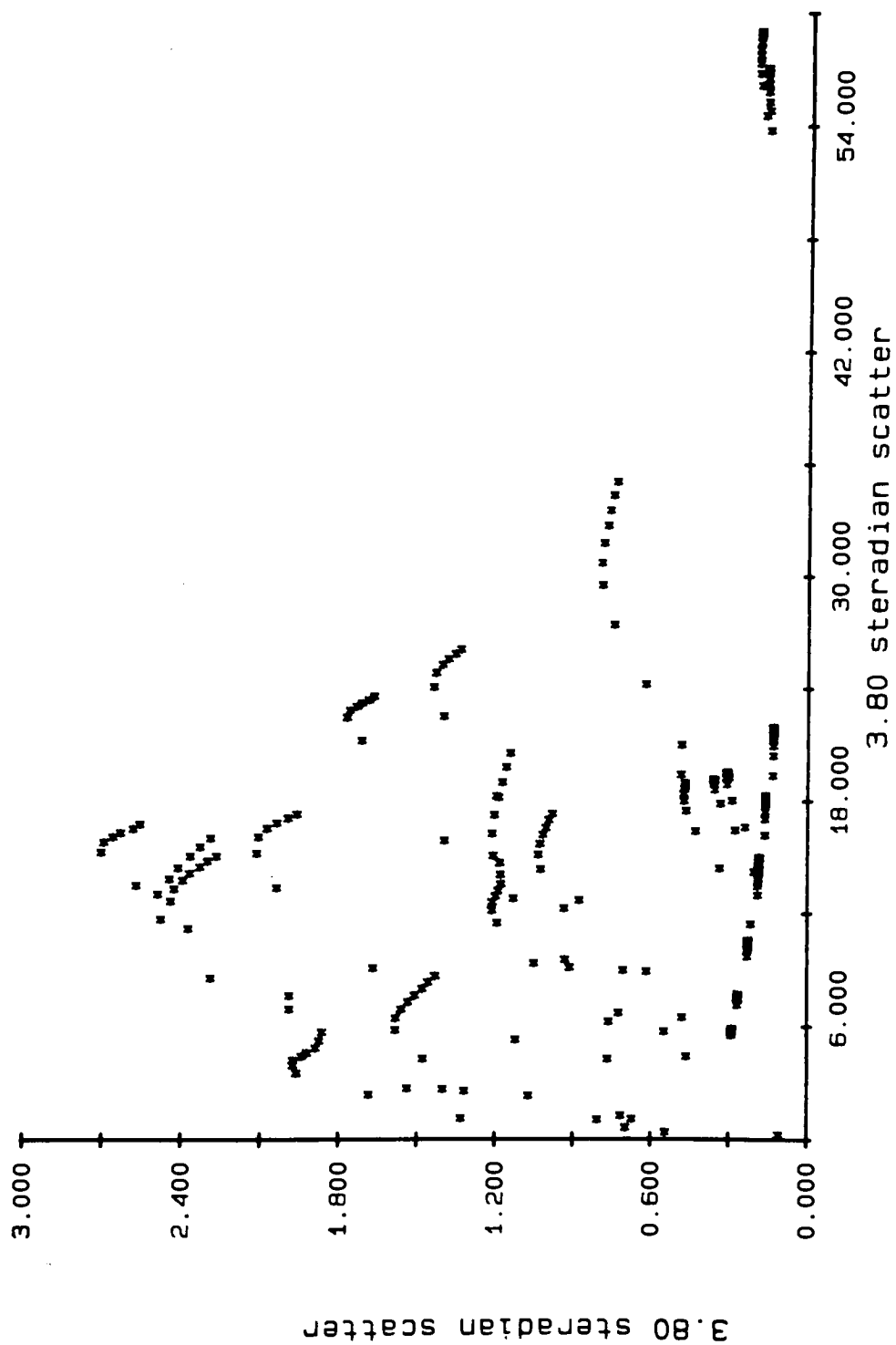


Figure 8

0.24 steradian vs 4pi scatter

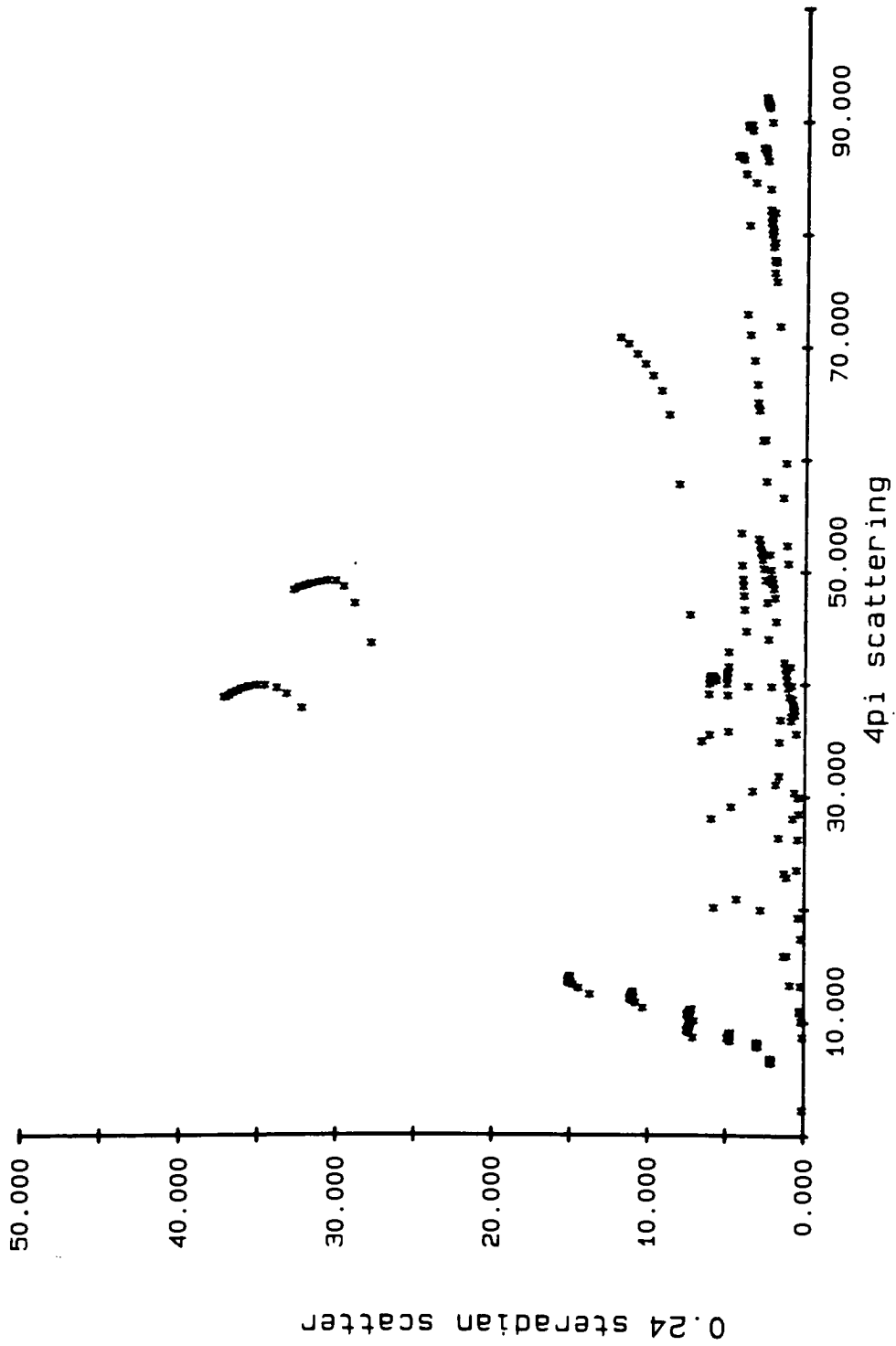


Figure 9

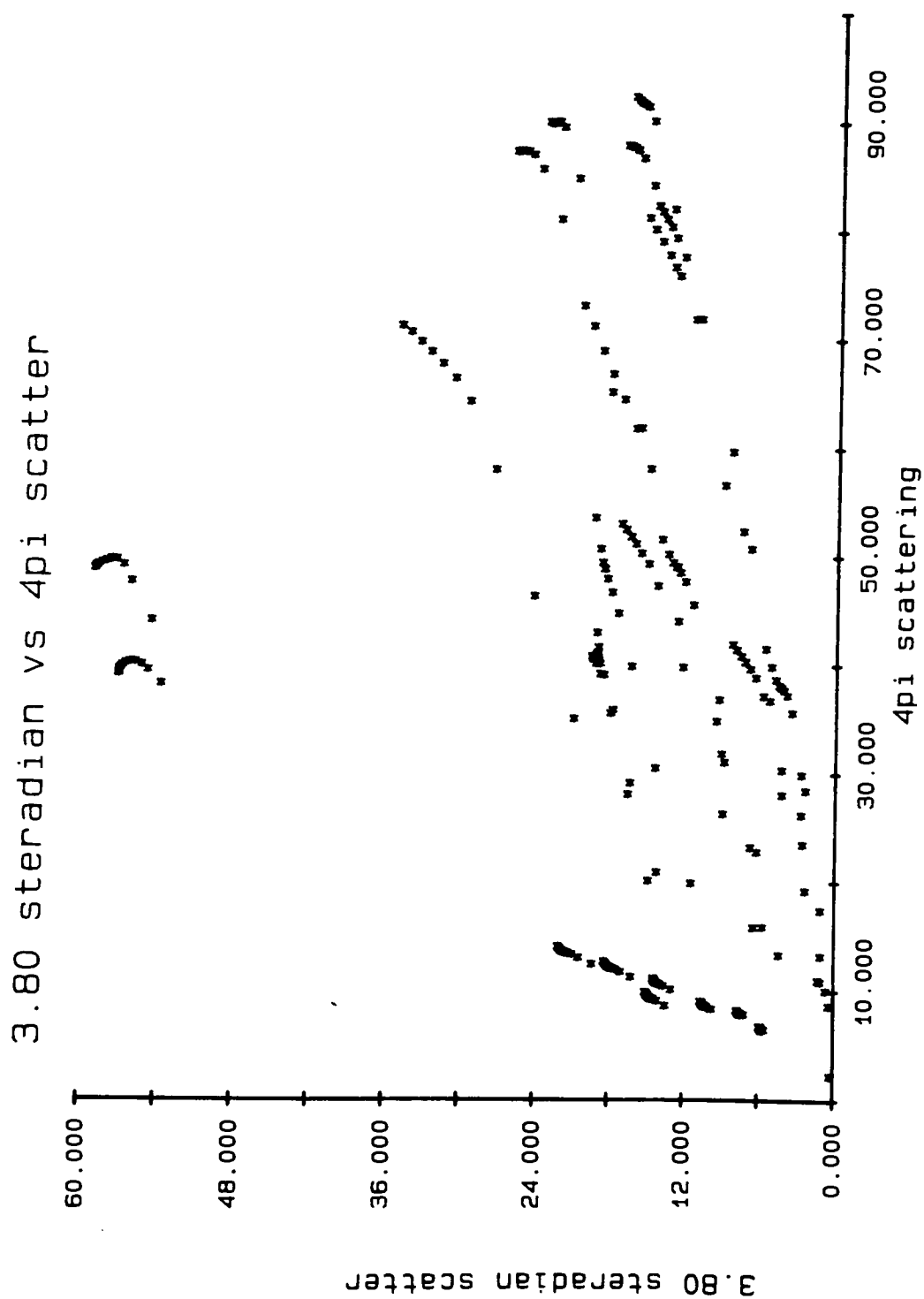


Figure 10

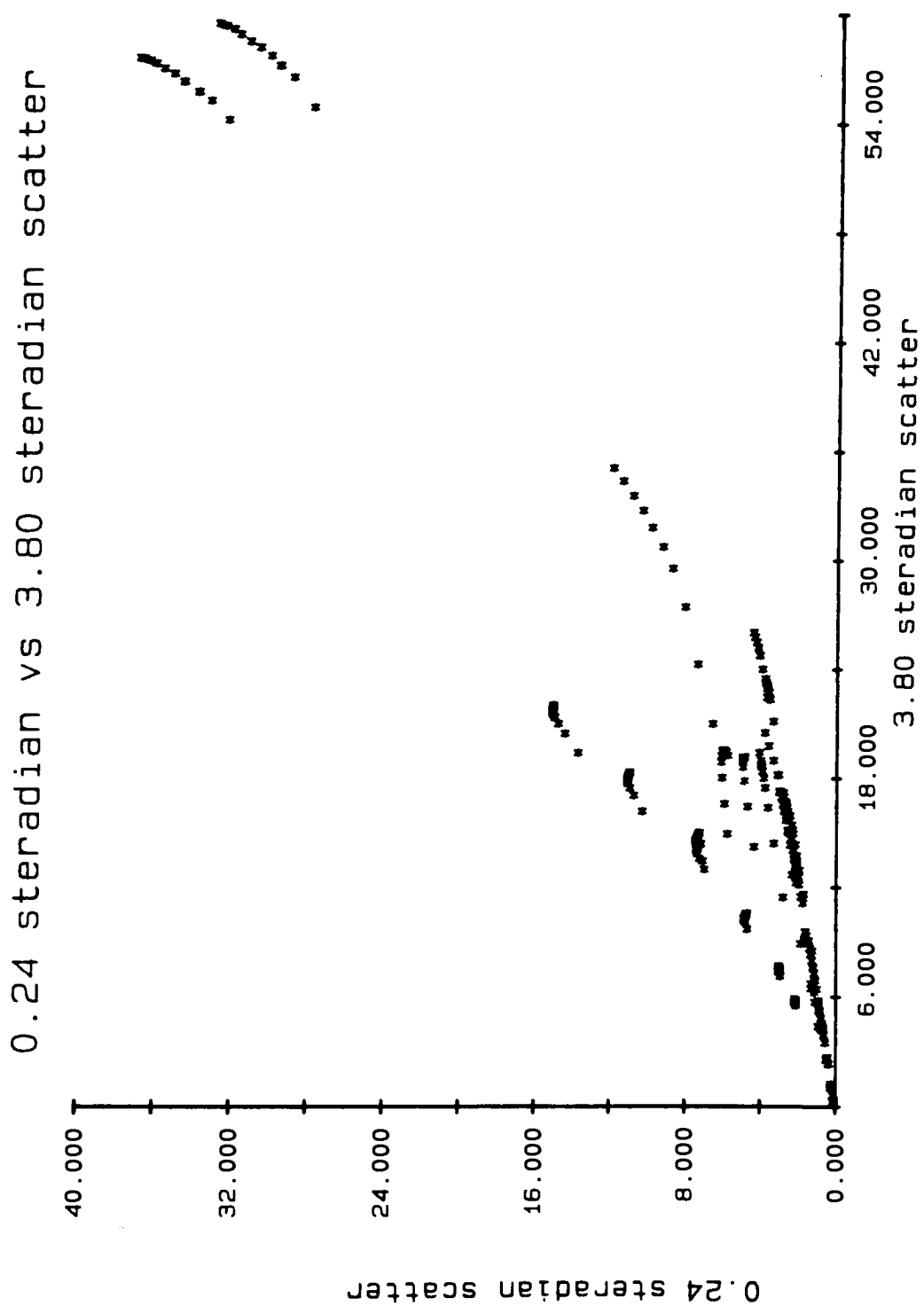


Figure 11

IV. DISCUSSION/CONCLUSION

The use of these simple alternate measurement techniques would be desirable for several reasons. Instrumentation would not have to be changed, and Kubelka-Munk methods have been shown to be a problem in the past when measuring solid turbid media. The methods described here for scatter do not model well the Kubelka-Munk technique in any area of scattering. All of the plots of scatter have various areas of trends that look promising, but those trends are false; not due to correlation, but due to one sample that was measured at several wavelengths. The change in spectral scatter was smooth for one sample, and therefore it shows up as a trend in the plot of one type of scatter to another. The discontinuities occur between different samples, and there appears to be no trend when just one type of sample is used for the comparison. The measurements were checked twice for repeatability, and were within the stated range for all methods. The disparity in the data might be explainable with more information about the plastic samples. Information such as pigment type, size and concentration were unknown quantities, and may prove to be useful in further research. Other errors are specific to the measurement itself.

It can be seen from table 1 that the correlation

between KM S and 4π scatter was 0.77. The plot shows that there is scattering of the data points. This could be due to fundamental differences in the samples or problems in the measurement. The 4π measurement was performed with a reduced beam size which traveled through the sample onto a small black patch for the scatter measurement. The specular port was also black, but its size was not variable. This caused more than just the specular reflection to be taken out of the measurement which caused additional error. Also, with the sample holder inside the sphere, the reading of the reference channel would be affected by the sample.

Table 1 also shows that the 4π absorption measurement correlates well with the Kubelka-Munk method. The best correlation occurs at the lower ranges of K. K's above 1.00 have less correlation, and it can be seen that perhaps an 3rd order equation would model it well. The absorption measurement did not suffer from the sphere problems that the scatter did. Also, the pigment size and distribution while affecting the absorptance, does not cause it, therefore the measurement did not suffer due to lack of information about the sample.

The comparison between the 0.24 steradian and Kubelka-Munk methods show little correlation at any range of Kubelka-Munk S. This is due to the lack of information in

the 0.24 steradian measurement. Since the measurement does not include the regular transmission, the amount of energy collected was low. Only the most highly scattering samples were able to give any information, and the correlation shown is negative.

This lack of measurable energy also plagued the 3.80 steradian scattering measurement. Even though it was collecting energy in over 10 times as much area as the above, it still suffered from lack of information. This was due to the surface reflection that did not enter the measurement, and the trapping out of the specular transmittance. There is a trade off in the transmission compartment measurement; if the beam size is large, more energy strikes the sample, but more gets taken out of the specular. If the beam is smaller, the energy removed for the specular is less, but the energy striking the sample is less. Another limitation to this method is the type of samples that can be measured. The measurement gives the most information to samples that have high scatter, and low absorptance, thus transparent or highly selective samples would give little or no information. One reason the Kubelka-Munk method works is that it looks at a large portion of the sample and collects all of the energy. The drawback is that then scatter includes that portion of the radiation that travels through and reflects off the sample

undeviated.

The comparison of the 4pi method to the transmission compartment measurements show that with the small angle of acceptance, the samples with lower scatter had higher correlation, and with the large angle, the samples with higher scatter had higher correlation. Therefore it may be valid to replace a 4pi scattering measurement with a transmission compartment scattering measurement.

The comparison of the between the two different transmission compartment measurements showed about equal correlation for all ranges of 0.24 steradian scatter. This is not surprising since the two measurements both suffer from the same problems, only to differing degrees.

The purpose of this research was to try alternate methods to conventional absorption and scattering measurements. From the above data, the 4pi absorption measurement best fits the Kubelka-Munk absorption coefficient. As for scatter, the 4pi method was the closest to the Kubelka-Munk scatter, but was not as accurate due to measurement flaws.

- -

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APPENDIX A

```
' Subroutine MATCHSCAN gets a scan from the Match Scan II
' by using the ST command. It takes the values and puts
' them in the variable RVAL(i) which comes from the
' /FILE.VAR/ common block.
' Written by Christopher H. Pearson for his BS thesis
' $include:'file.var'
```

```
sub matchscan static
```

```
open "com1: 4800,n,8,1,cs0,ds0,cd0,asc" AS #1
print #1, CHR$(3)
call rest (10)
print #1, "ST"
call rest (10)

print " WL"," %R"
```

```
Gimmie:
```

```
input #1, a : if (a < 360) or (a > 830) then goto gimmie
if a = endingwave then print #1, chr$(3)
input #1, b

print a,b

k=a/5 - 71
rval(k) = b
if a = endingwave then goto enough
goto Gimmie
```

```
Enough:
```

```
close #1
```

```
end sub
```



```
' subroutine MATCHINIT initializes the Match scan and sets
' it up for collecting data from 380 to 70 nm in 10 nm
' increments. It sets to correct the data and not to print
' out color space calculations.
```

```
' Written by Christopher H. Pearson for his BS thesis
```

```
'$include:'file.var'
```

```
sub matchinit static
  startingwave=380.0
  endingwave=700.0
  waveincrement=10.0
  open "com1: 4800,n,8,1,cs0,ds0,cd0,asc" AS #1
  print #1, CHR$(3)
  call rest(10)
  print #1, "WS=380.0"
  call rest(10)
  print #1, "WE=700.0"
  call rest(10)
  print #1, "WI=10.0"
  call rest(10)
  print #1, "CR=1"
  call rest(10)
  print #1, "PR=1"
  call rest(10)
  print #1, "PT=0"
  close #1
```

```
end sub
```

```
' Subroutine REST gets an integer and loops 100 times  
' that number and returns.  
' Written by Christopher H. Pearson for his BS thesis
```

```
sub rest(num%) static
```

```
    if num% < 1 then num% = 1  
    for i = 1 to num%*100  
    next i
```

```
end sub
```

```

' Subroutine GETFILENAME allows the user to enter the name
' of a sample file to be read. The subroutine also allows
' the specification of a drive other than the default.
' filename$ - the variable for the filename.
' row - the row where the file name is displayed.
' col - the starting column where the filename is displayed.
' exitcode - a code that when is greater than 1 allows for
'           exit without returning a file name.
'
' To use this subroutine you must pass it the row and column
' where you want the name to be displayed. The routine then
' returns the file name in the string FILENAME$. If the user
' presses the 'Exit' key or 'Ctrl-C' then routine then stops,
' gives EXITCODE the value of one and returns to the calling
' program without a file name.
'
' the call must be in the form as follows:
'
' CALL GETFILENAME(FILENAME$,row%,col%,EXITCODE)
'
' Written by Christopher H. Pearson for his BS thesis

```

```

sub getfilename (filename$,row%,col%,exitcode) static

```

```

dim k%(10)
c% = 0
l% = 1
filename$=""
exitcode = 0
key 5,chr$(3)

```

```

locate row%,col%

```

```

ask:

```

```

q$ = inkey$
if q$="" then goto ask
q% = asc(q$)
if q% = 3 then goto leave
if q% = 13 then goto done
if q% = 8 then goto backspace
if l% > 8 then goto ask
if q% = 58 and c% = 1 then goto colon
if q% < 48 then goto ask
if q% > 57 and q% < 65 then goto ask

```

```

if q% > 90 and q% < 97 then goto ask
if q% > 122 then goto ask
if q% > 96 then q% = q% - 32
k%(c%) = q%
c% = c% + 1
l% = l% + 1

```

```

locate row%,col% - 1 + c%
print chr$(q%);

```

```

goto ask

```

```

colon:

```

```

if ((k%(0) < 64) and (k%(0) > 91)) then goto ask
k%(1) = 58
l% = 1
c% = c% + 1
locate row%,col% - 1 + c%
print chr$(q%);
goto ask

```

```

backspace:

```

```

c% = c% - 1
if c% < 0 then c% = 0
locate row%,col% + c%
print chr$(32);
l% = l% - 1
if l% < 1 then l% = 1
goto ask

```

```

leave:

```

```

exitcode = 1
exit sub

```

```

done:

```

```

for i = 0 to c% - 1
filename$ = filename$ + chr$(k%(i))
next i
exitcode = 0
end sub

```

```

' subroutine SAVEFILE saves sample file to disk.

' FILENAME$ is passed to GETFILE or SAVEFILE
' STARTINGWAVE - the starting wavelength for this scan
' ENDINGWAVE - the ending wavelength for this scan
' WAVEINCREMENT - the wavelength increment
' RVAL(95) - the reflection or transmittance values.
' DESCRIPT$ - the discription of the file
' EXITCODE - error flag when set to 1 the file was not found
'             or already exists.
'
' To use this subroutine, the calling program must have the
' common block /FILE.VAR/. The file name to be saved to (less
' the extension) must be in the string FILENAME$. This can be
' accomplished by using the GETFILENAME subroutine or some
' other method. Also, the reflectance or transmittance data
' must be in the RVAL() array. This array is static in that
' the information in any element is from the same wavelength.
' thus if the data went from 380nm to 700nm in 10nm increments,
' the data in the array would start at element 5, end at
' element 69, and have values in every other element.
' This subroutine saves data in a random access file with only
' one record 416 bytes long. The first 20 bytes are for the
' description from DESCRIPT$. The next 12 contain the starting
' ending, and increments of the wavelength protion of the data
' in that order. The last 384 bytes is broken up into 2 fields,
' the first containing the first 48 data points and the second
' contains the last 47 data points.
' This subroutine also gets one variable passed to it via the
' call, this is the EXITCODE. This variable is set non-zero if
' the user exits the subroutine without saving any data.
' Therefore upon returning from SAVEFILE check the value of the
' variable you passed to EXITCODE, if it is non-zero, no data
' was stored. This could be due to the fact that the file name
' that was passed was already on the disk, and the user did not
' want to write over it. In this case the calling routine should
' ask the user for another file name, and recall SAVEFILE.
' for example the call could look something like:
'
' CALL SAVEFILE(CODE)
' IF CODE > 0 THEN GOTO GETNAME
'
' GETNAME could be a small routine in the calling program that
' would ask the user fo a filename and thenn move back down to
' the call to SAVEFILE.
' Written by Christopher H. Pearson for his BS thesis
' at Bausch and Lomb co. Inc.

```

```
' $include:'file.var'
```

```
SUB SAVEFILE(exitcode) STATIC
```

```
    exitcode = 0
    ok = 0
    c$ = ""
    d$ = ""
    e$ = ""
```

```
start:
```

```
    open "r", #2 ,filename$ + ".sam",416
```

```
    field #2 , 20 as t$, 12 as w$, 192 as a$, 192 as b$
```

```
    if (lof(2) > 0) and (ok < 1) then close (2):_
    goto exists
```

```
    for i = 0 to 47
    c$ = c$ + mks$(rval(i + 1))
    next i
```

```
    for i = 0 to 46
    d$ = d$ + mks$(rval(i + 49))
    next i
```

```
    e$ = mks$(startingwave)
    e$ = e$ + mks$(endingwave)
    e$ = e$ + mks$(waveincrement)
```

```
    lset t$ = descript$
    lset w$ = e$
    lset a$ = c$
    lset b$ = d$
```

```
    put #2,1
```

```
    close #2
```

```
    goto fin
```

```
exists:
```

```
    locate 22,1
```

```
    print filename$;
```

```
    print " already exists! Do you want to Delete it and write ove
```

```
    locate 23,1
```

```
    print "or Enter a new file name (D/E)? ";
```

```
ask:
  q$ = inkey$
  if q$ = "" then goto ask

  if (q$ = "D") or (q$ = "d") then ok = 1:_
  goto start

  if (q$ = "E") or (q$ = "e") then exitcode = 1:_
  goto fin

  goto ask

fin:  END SUB
```

```

' Subroutine get file gets a disk file.
' FILENAME$ is passed to GETFILE and getfile returns:
' STARTINGWAVE - the starting wavelength for this scan
' ENDINGWAVE - the ending wavelength for this scan
' WAVEINCREMENT - the wavelength increment
' RVAL(95) - the reflection or transmittance values.
' DESCRIPT$ - the discription of the file
' EXITCODE - error flag when set to 1 the file was not found.

' To use this subroutine the user must place an 8 or 10 characte
' file name (with or without a drive specification) into the
' common variable FILENAME$ found in the common block labeled
' /FILE.VAR/. This can be accomplished by using the
' GETFILENAME subroutine or some other method. This subroutine
' then opens that file name with the extension .SAM and
' returns the following information:
'   The starting wavelength in STARTINGWAVE
'   The ending wavelength in ENDINGWAVE
'   The wavelength increment in WAVEINCREMENT
'   The description of the scan in DESCRIPT$
'   The data is put into RVAL array. This array has a capacity
'   for storing values from 360nm to 830nm in 5nm increments
'   thus the reasoning behind 95 elements. The data in this
'   array is static, that is the value for 400nm is always in
'   the 9th element of the array, thus the need for the starting
'   and ending wavelengths as well as the wavelength increment
'   for pulling out the data from this array properly for
'   calculations, plotting, etc.

' All of these variables come out of the subroutine through
' the /FILE.VAR/ common block. There is another variable,
' called EXITCODE that is passed into the subroutine through
' the call. This is a code that will return a non-zero number
' if the subroutine has any problem opening the file.
' an example of the call might be:

' FILENAME$ = "A:RED"
' CALL GETFILE(CODE)

' Where CODE corresponds to EXITCODE in the subroutine. Upon
' returning from the subroutine check the value of CODE (or
' whatever you called it) and if it is non-zero go to an exit
' routine. For example:

'       IF CODE > 0 THEN GOTO EXIT
' EXIT: PRINT"ERROR OPENING FILE ";FILENAME$;".SAM"
'       STOP

```


' Written by Christopher H. Pearson for his BS thesis

' \$include:'file.var'

SUB GETFILE(exitcode) STATIC

exitcode = 0

open "r", #2 ,filename\$ + ".sam",416

field #2 , 20 as t\$, 12 as w\$, 192 as a\$, 192 as b\$

get #2

```
if lof(2) < 416 then close #2 :_
    kill filename$+".sam" :_
    exitcode = 1 :_
    goto oop
```

descript\$ = t\$

```
for i = 0 to 47
    q$ = mid$(a$,i*4 + 1,4)
    rval(i + 1) = cvs(q$)
next i
```

```
for i = 0 to 46
    q$ = mid$(b$,i*4 + 1,4)
    rval(i + 49) = cvs(q$)
next i
```

```
q$ = mid$(w$,1,4)
startingwave = cvs(q$)
```

```
q$ = mid$(w$,5,4)
endingwave = cvs(q$)
```

```
q$ = mid$(w$,9,4)
waveincrement = cvs(q$)
```

close #2

```
--
oop:  END SUB
```

```
' Subroutine GETSTRING allows the user to enter a string
' of a fixed maximum length.
,
' strng$ - the variable for the filename.
' lngth% - is the maximum length for the string.
' row% - the row where the file name is displayed.
' col% - the starting column where the filename is displayed.
,
' To use this subroutine you must pass it the row and column
' where you want the string to be displayed. The routine then
' returns the file name in the string FILENAME$. If the user
' presses the 'Exit' key or 'Ctrl-C' then routine then stops,
' gives EXITCODE the value of one and returns to the calling
' program without a file name.

' the call must be in the form as follows:

' CALL GETSTRING(strng$,LNGTH%,ROW%,COL%)

' Written by Christopher H. Pearson for his BS thesis

' last updated 3-21-85 chp
```

```
sub getstring (strng$,lngth%,row%,col%) static
```

```
dim k%(256)
c% = 0
strng$=""
```

```
locate row%,col%
```

```
ask:
```

```
q$ = inkey$
if q$="" then goto ask
q% = asc(q$)
if q% = 13 then goto done
if q% = 8 then goto backspace
if c% >= lngth% then goto ask
if q% < 32 then goto ask
if q% > 126 then goto ask
k%(c%) = q%
c% = c% + 1
```

```
locate row%,col% - 1 + c%
print chr$(q%);
```

```
goto ask
```

```
backspace:
    c% = c% - 1
    if c% < 0 then c% = 0
    locate row%,col% + c%
    print chr$(32);
    goto ask

done:
    for i% = 0 to c% - 1
        strng$ = strng$ + chr$(k%(i%))
    next i%
end sub
```

```

' Program PRINTFIL prints out up to 3 data files across
' a page.
' Written by Christopher H. Pearson for his BS thesis

' $include:'file.var'

dim dt(3,95),des$(3)

strt:
  cls
  locate 12,1
  print"Enter the number of files you want printed: ";

ask1:
  q$ = inkey$
  if q$ = "" then goto ask1
  print q$;
  q = val(q$)
  if (q<1) or (q>3) then goto strt
  np = q

  for i = 1 to np
get01:
  cls
  locate 12,1
  print "Enter file name to be printed"
  print "-->          <--"
  call getfilename(f$,13,4,oops)
  if oops > 0 then oops = 0 : goto get01
  filename$ = f$

  call getfile(oops)
  if oops > 0 then oops = 0 : goto nd

  s = (startingwave - 360)/5 + 1
  e = 95 - (830 - endingwave)/5
  inc = waveincrement/5

  for j = s to e step inc
  dt(i,j) = rval(j)
  next j

  des$(i) = descript$

  next i

```

```

title:
    cls
    locate 12,1
    print "Enter a title for the printout below"
    call getstring(st$,80,13,1)

prnt:
    lprint "
    lprint "Thesis data"
    lprint st$
    lprint
    lprint "      WL      ";
    for i = 1 to np
    w = 22 - len(des$(i))
    for j = 1 to w/2
    lprint " ";
    next j
    lprint des$(i);
    for j = 1 to w/2
    lprint " ";
    next j
    next i
    lprint

    for i = s to e step inc
    lprint " "; using "###.#"; 355 + i*5;
    lprint "> ";

    for j = 1 to np
    lprint " "; using "##.####"; dt(j,i);
    lprint " ";
    next j
    lprint
    next i
    lprint chr$(12);

ask2:
    cls
    locate 12,1
    print "Do you want to print more files (Y/N)? ";

```

```
ask3:    q$ = inkey$
         if q$ = "" then goto ask3
         print q$;
         if (q$ = "Y") or (q$ = "y") then goto strt
         if (q$ = "N") or (q$ = "n") then goto nd
         goto ask2

nd:      end
```

```
' CDES corrects the description of data files
' Written by Christopher H. Pearson for his BS thesis
' $include:'file.var'
```

```
strt:
  cls
  locate 2,1
  print "Enter then name of the data file to be corrected"
  print "-->          <--"
  call getfilename(f$,3,4,oops)
  if oops > 0 then goto nd
  filename$ = f$
  call getfile(oops)
  if oops > 0 then goto nd
  locate 4,1
  print "The current description is: ";descript$
  print "Enter the new description below"
  print "-->          <--"
  call getstring(st$,20,6,4)
  descript$ = st$
  call savefile(oops)
  if oops > 0 then goto nd

ask:
  locate 15,1
  print "Do you want to correct another (Y/N)? "

ask1:
  q$ = inkey$
  if (q$ = "Y") or (q$ = "y") then goto strt
  if (q$ = "N") or (q$ = "n") then goto nd
  goto ask1

nd:
  end
```

APPENDIX B

```
' Program KMSCAN
' Main program to compute k and s
' Written by Christopher H. Pearson for his BS thesis
' $include:'file.var'
' $include:'kmsubs.bas'
```

```
dim refb(95),refw(95),refob(95),refow(95),k(95),s(95),_
    a(95),b(95)
```

```
strtl:
    cls
    print"First start with the white tile:"
    print"Do you want to scan the tile or retrieve it from disk (S/R)?"
```

```
gtl:
    q$ = inkey$
    if q$ = "" then goto gtl
    print q$;
    if (q$ = "S") or (q$ = "s") then goto scanl
    if (q$ = "R") or (q$ = "r") then goto retrl
    goto strtl
```

```
scanl:
    gosub gtides
    cls
    locate 12,1
    print"Place the white tile in the port and press <Return> to"
    print"start the scan..."
```

```
gtl1:
    q$ = inkey$
    if q$ = chr$(13) then goto scanl1
    goto gtl1
```

```
scanl1:
    call matchinit

    call matchscan

    gosub sagain

    goto swt
```



```

retr1:
    cls
    locate 22,1
    print "Enter the filename of the white backround"
    print "-->          <--";
    call getfilename(f$,23,4,oops)
    filename$ = f$
    call getfile(oops)
    if oops > 0 then oops = 0 : goto retr1

swt:
    gosub cl
    for i = s to e step inc
print i,rval(i)
    refw(i) = rval(i)
    next i

strt2:
    cls
    print"Next the black tile:"
    print"Do you want to scan the tile or retrieve it from disk (S/R

gt2:
    q$ = inkey$
    if q$ = "" then goto gt2
    print q$;
    if (q$ = "S") or (q$ = "s") then goto scan2
    if (q$ = "R") or (q$ = "r") then goto retr2
    goto strt2

scan2:
    gosub gtDES
    cls
    locate 12,1
    print"Place the black tile in the port and press <Return> to"
    print"start the scan..."

gt22:
    q$ = inkey$
    if q$ = "" then goto gt22
    if q$ = chr$(13) then goto scan22
    goto gt22

```

```

scan22:
    call matchinit

    call matchscan

    gosub sagain

    goto sbt

retr2:
    cls
    locate 22,1
    print "Enter the filename of the black background"
    print "-->          <--";
    call getfilename(f$,23,4,oops)
    filename$ = f$
    call getfile(oops)
    if oops > 0 then oops = 0 : goto retr2

sbt:
    gosub cl
    for i = s to e step inc
        refb(i) = rval(i)
    next i

strt3:
    cls
    print "Now the sample over white:"
    print "Do you want to scan the sample or retrieve it from disk (S,

gt3:
    q$ = inkey$
    if q$ = "" then goto gt3
    print q$;
    if (q$ = "S") or (q$ = "s") then goto scan3
    if (q$ = "R") or (q$ = "r") then goto retr3
    goto strt3

scan3:
    gosub gt des
    cls
    locate 12,1
    print "Place the sample over white in the port and press <Return>"
    print "start the scan..."

```

```

gt33:
    q$ = inkey$
    if q$ = "" then goto gt33
    if q$ = chr$(13) then goto scan33
    goto gt33

scan33:
    call matchinit

    call matchscan

    gosub sagain

    goto ssow

retr3:
    cls
    locate 22,1
    print "Enter the filename of the sample over white"
    print "-->          <--";
    call getfilename(f$,23,4,oops)
    filename$ = f$
    call getfile(oops)
    if oops > 0 then oops = 0 : goto retr3

ssow:
    gosub cl
    for i = s to e step inc
        refow(i) = rval(i)
    next i

strt4:
    cls
    print "And now the sample over black:"
    print "Do you want to scan the sample or retrieve it from disk (S

gt4:
    q$ = inkey$
    if q$ = "" then goto gt4
    print q$;
    if (q$ = "S") or (q$ = "s") then goto scan4
    if (q$ = "R") or (q$ = "r") then goto retr4
    goto strt4

```

```

scan4:
    gosub gt44
    cls
    locate 12,1
    print "Place the sample over black in the port and press <Return>"
    print "start the scan..."

gt44:
    q$ = inkey$
    if q$ = "" then goto gt44
    if q$ = chr$(13) then goto scan4
    goto gt44

scan44:
    call matchinit

    call matchscan

    gosub sagain

    goto ssob

retr4:
    cls
    locate 22,1
    print "Enter the filename of the sample over black"
    print "-->          <--";
    call getfilename(f$,23,4,oops)
    filename$ = f$
    call getfile(oops)
    if oops > 0 then oops = 0 : goto retr4

ssob:
    gosub cl
    for i = s to e step inc
    refob(i) = rval(i)
    next i

ask:
    cls
    locate 12,1
    print "Correct for surface (Y/N)?";

```

```

ask0:
  q$ = inkey$
  if (q$ = "Y") or (q$ = "y") then goto corr
  if (q$ = "N") or (q$ = "n") then goto calc
  goto ask0

corr:

  for i = s to e step inc
    refb(i) = fnsaund(refb(i))
    refw(i) = fnsaund(refw(i))
    refob(i) = fnsaund(refob(i))
    refow(i) = fnsaund(refow(i))
  next i

calc:

  for i = s to e step inc

    rw = refw(i)
    row = refow(i)
    rb = refb(i)
    rob = refob(i)

    a(i) = fnkma(rob,row,rb,rw)

    al = a(i)

    b(i) = fnkmb(al)

    al = a(i)
    bl = b(i)
    rb = refb(i)
    rob = refob(i)

    s(i) = fnkms(al,bl,rob,rb)

    al = a(i)
    sl = s(i)

    k(i) = fnkmk(al,sl)

  next i

-
cls

```

```

print "WL","K","S"
for i = s to e step inc
wl = 5*i + 355
print wl,k(i),s(i)
next i
locate 23,1
print:print

locate 22,1
print "Enter a discription for the absorbance data"
print "-->          <--";
call getstring(st$,20,23,4)
descript$ = st$

```

fsavel:

```

cls
locate 22,1
print "Enter the filename for the absorbance data"
print "-->          <--";
call getfilename(f$,23,4,oops)
filename$ = f$
for i = s to e step inc
rval(i) = k(i)
next i
call savefile(oops)
if oops > 0 then oops = 0 : goto fsavel

cls
locate 22,1
print "Enter a discription for the scattering data"
print "-->          <--";
call getstring(st$,20,23,4)
descript$ = st$

```

fsave2:

```

cls
locate 22,1
print "Enter the filename for the scattering data"
print "-->          <--";
call getfilename(f$,23,4,oops)
filename$ = f$
for i = s to e step inc
rval(i) = s(i)
next i
call savefile(oops)
if oops > 0 then oops = 0 : goto fsave2

```

```

ask1:
  cls
  locate 12,1
  print "Calculate more samples using same background (Y/N)?";

ask2:
  q$ = inkey$
  if (q$ = "Y") or (q$ = "y") then goto strt3
  if (q$ = "N") or (q$ = "n") then goto ask3
  goto ask2

ask3:
  cls
  locate 12,1
  print "Calculate more samples using different background (Y/N)?";

ask4:
  q$ = inkey$
  if (q$ = "Y") or (q$ = "y") then goto strt1
  if (q$ = "N") or (q$ = "n") then goto nd
  goto ask4

nd:
  end

gtdes:
  locate 12,1
  print "Enter up to a 20 character description of this sample."
  locate 13,1
  print "-->                                <--"
  call getstring(st$,20,13,4)
  descript$ = st$
return

sagain:
  cls
  locate 12,1
  print "Do you wanna save this scan? (Y/N)?"

q1:
  q$ = inkey$
  if (q$ = "Y") or (q$ = "y") then goto sf
  if (q$ = "N") or (q$ = "n") then return
  goto q1

```

```
sf:
  cls
  locate 12,1
  print "Enter a file name to save the file to:"
  locate 13,1
  print "-->          <--"
  call getfilename(filename$,13,4,oops)
  if oops > 0 then goto again:
  call savefile(oops)
  if oops > 0 then goto sf
return

cl:
  s = (startingwave - 360)/5 + 1
  e = 95 - (830 - endingwave)/5
  inc = waveincrement/5
return
```


' File KMSUBS.BAS is a group of subroutines that do all
 ' of the incomplete hiding treatment of Kubelka-Munk scatter
 ' and absorption.
 ' Written by Christopher H. Pearson for his BS thesis

def fnsaund(r)

' r - uncorrected reflectance
 ' fnsaund - internal reflectance using Saunderson
 ' corrections

if r <= 0 then fnsaund = 0 :_
 exit def

k1 = 0.04
 k2 = 0.4

temp = r - k1
 if temp <= 0 then fnsaund = 0 :_
 exit def

fnsaund = temp/(1.0 - k1 - k2 + (r*k2))

end def

def fnkma(rb,rw,rbb,rwb)

' rb - reflectance over black
 ' rw - reflectance over white
 ' rbb - reflectance of black background
 ' rwb - reflectance of white background
 ' fnkma - Kubelka-Munk a

x1 = rw - rwb
 y1 = rb - rbb
 z1 = x1 * (1.0 + rb * rbb) - y1 * (1.0 + rw * rwb)

fnkma = z1/(x1 * (rbb + rb) - y1 * (rwb + rw))

end def

def fnkmb(a)

' a - Kubelka-Munk a
 ' fnkmb - Kubelka-Munk b

fnkmb = (a^2.0 - 1.0)^0.5

```

end def

def fnarcoth(x2)
    ' x2          - argument
    ' fnarcoth - inverse hyperbolic cotangent

    y2 = 1.0 + x2
    z2 = x2 - 1.0
    qq = log(y2/z2)/2.0
    fnarcoth = qq
end def

def fnkms(a,b,rw,rwb)
    ' rw          - reflectance over white
    ' rwb         - reflectance of white background
    ' a           - Kubelka-Munk a
    ' b           - Kubelka-Munk b
    ' fnkms       - Kubelka-Munk s

    x3 = (a - rw)/b
    y3 = (a - rwb)/b
    z4 = fnarcoth(x3)
    z5 = fnarcoth(y3)
    qq = (z4 - z5)/b
    fnkms = qq
end def

def fnkmk(a,s)
    ' a           - Kubelka-Munk a
    ' s           - Kubelka-Munk s
    ' fnkmk       - Kubelka-Munk k

    fnkmk = (a - 1.0)*s
end def

```

APPENDIX C

```
' Program MATCH
' 4pi data collection program for the Match Scan II
' spectrophotometer.
' To use this program, you must have individual files for
' calibration of the specular included and excluded called
' SINCAL.SAM and SEXCAL.SAM respectively. This sets up for
' the calibration and the measurement of scatter and absorption
' of the same sample.
```

```
' Written by Christopher H. Pearson for his BS thesis
```

```
' $include:'file.var'
```

```
dim zero(95),temp(95),sexcal(95),sincal(95)
```

```
call initnocr
```

```
s = (startingwave - 360)/5 + 1
```

```
e = 95 - (830 - endingwave)/5
```

```
inc = waveincrement/5
```

```
filename$ = "SEXCAL"
```

```
call getfile(oops)
```

```
if oops > 0 then goto nd
```

```
for i = s to e step inc
```

```
temp(i) = rval(i)
```

```
next i
```

```
cls
```

```
locate 12,1
```

```
print "Move the specular slide to the SEX postion"
```

```
print "and press <Return> to calibrate for specular excluded";
```

```
call:
```

```
q$ = inkey$
```

```
if q$ = chr$(3) then goto nd
```

```
if q$ <> chr$(13) then goto call
```

```
call matchscan
```

```
for i = s to e step inc
```

```
sexcal(i) = temp(i)/rval(i)
```

```
next i
```

```
filename$ = "SINCAL"
```

```
call getfile(oops)
```

```
if oops > 0 then goto nd
```

```
for i = s to e step inc
```

```
temp(i) = rval(i)
```

```
next i
```

```

cls
locate 12,1
print "now move the specular slide to the SIN postion"
print "and press <Return> to calibrate for specular included";

```

cal2:

```

q$ = inkey$
if q$ = chr$(3) then goto nd
if q$ <> chr$(13) then goto cal2

```

```

call matchscan
for i = s to e step inc
sincal(i) = temp(i)/rval(i)
next i

```

```

cls
locate 12,1
print "Now remove the 4pi attachment and place the black backgrou
print "on it. Put it back in the sphear moving the slide to the :
print "position and press <Return> to calibrate for the zero poi

```

calz:

```

q$ = inkey$
if q$ = chr$(3) then goto nd
if q$ <> chr$(13) then goto calz

```

```

call matchscan
for i = s to e step inc
zero(i) = rval(i)
next i

```

strt:

```

cls
locate 11,1
print "With the specular slide in the excluded mode,"
print "mount the sample with the black patch and enter up to"
print "a 20 character description of the scattering sample"
locate 14,1
print "-->

```

```

call getstring(st$,20,14,4)

```

```

descript$ = st$
cls
locate 12,1
print "Prepare sample and press <Return> to start scan."

```

scask:

```

q$ = inkey$
if q$ = chr$(3) then goto nd
if q$ <> chr$(13) then goto scask

call matchscan
print " W1","Scat"
for i = s to e step inc
rval(i) = sexcal(i)*rval(i) - zero(i)
print 355 + i*5,rval(i)
next i

gosub savfil

```

abstrt:

```

cls
locate 11,1
print "With the specular slide in the included mode,"
print "mount the sample with out the black patch and enter"
print "up to a 20 character description of the absorbing sample"
locate 14,1
print "-->                                <--";

call getstring(st$,20,14,4)

descript$ = st$
cls
locate 12,1
print "Prepare sample and press <Return> to start scan."

```

abask:

```

q$ = inkey$
if q$ = chr$(3) then goto nd
if q$ <> chr$(13) then goto abask

call matchscan
print " W1","Abs"
for i = s to e step inc
rval(i) = 100.0 - sincal(i)*rval(i)
print 355 + i*5,rval(i)
next i

gosub savfil

```

ask2:

```

cls
locate 12,1
print "Collect more data (Y/N)? "

```

```

ask3:
    q$ = inkey$
    if q$ = "" then goto ask3
    if (q$ = "Y") or (q$ = "y") then goto strt
    if (q$ = "N") or (q$ = "n") then goto nd:
    goto ask2

nd:
    end

savfil:
    cls
    locate 12,1
    print"Do you wanna save this scan (Y/N)?";

sfask:
    q$ = inkey$
    if (q$ = "Y") or (q$ = "y") then goto sf
    if (q$ = "N") or (q$ = "n") then return
    goto sfask

sf:
    cls
    locate 12,1
    print "Enter a file name to save the file to:"
    locate 13,1
    print "-->          <--"
    call getfilename(filename$,13,4,oops)
    if oops > 0 then goto savfil:
    call savefile(oops)
    if oops > 0 then goto sf

return

```

```
' subroutine INITNOCR initializes the Match scan and sets
' it up for collecting data from 380 to 70 nm in 10 nm
' increments. It sets not to correct the data and not to print
' out color space calculations.
' Written by Christopher H. Pearson for his BS thesis
```

```
'$include:'file.var'
```

```
sub initnocr static
  startingwave=380.0
  endingwave=700.0
  waveincrement=10.0
  open "com1: 4800,n,8,1,cs0,ds0,cd0,asc" AS #1
  print #1, CHR$(3)
  call rest(10)
  print #1, "WS=380.0"
  call rest(10)
  print #1, "WE=700.0"
  call rest(10)
  print #1, "WI=10.0"
  call rest(10)
  print #1, "CR=0"
  call rest(10)
  print #1, "PR=1"
  call rest(10)
  print #1, "PT=0"
  call rest(10)
  print #1, "SC=2"
  close #1

end sub
```

APPENDIX D

```

' TSCAN

' Main data collection program for the Match Scan II
' spectrophotometer.
' Written by Christopher H. Pearson for his BS thesis

' $include:'file.var'

dim zero(95),temp(95)

call matchinit

s = (startingwave - 360)/5 + 1
e = 95 - (830 - endingwave)/5
inc = waveincrement/5

strt:
  cls

  locate 12,1
  print "Enter up to a 20 character description of this sample."
  locate 13,1
  print "-->                                <--"

  call getstring(st$,20,13,4)

  descript$ = st$
  cls
  locate 12,1
  print "Prepare sample and press <Return> to start scan."

ask:
  q$ = inkey$
  if q$ = chr$(3) then goto nd
  if q$ <> chr$(13) then goto ask

  call matchscan

sagain:
  cls
  locate 12,1
  print "Do you wanna save this scan? (Y/N)?

ask1:
  q$ = inkey$
  if (q$ = "Y") or (q$ = "y") then goto sf
  if (q$ = "N") or (q$ = "n") then goto ask2
  goto ask1

```



```
sf:
    cls
    locate 12,1
    print "Enter a file name to save the file to:"
    locate 13,1
    print "-->          <--"
    call getfilename(filename$,13,4,oops)
    if oops > 0 then goto sagain:
    call savefile(oops)
    if oops > 0 then goto sf

ask2:
    cls
    locate 12,1
    print "Collect more data (Y/N)? "

ask3:
    q$ = inkey$
    if q$ = "" then goto ask3
    if (q$ = "Y") or (q$ = "y") then goto strt
    if (q$ = "N") or (q$ = "n") then goto nd:
    goto ask2

nd:
    end
```

Vita

Christopher H. Pearson was born August 25, 1962 in Mt. Holly N.J. He spent his younger years living in the south side of Chicago, and then moved to Springfield Illinois. He became interested in photography as a science while working at Southern Illinois University in their bio-medical photography department. This led him to Rochester Institute of Technology where he completed this monograph. His future is as unsure as any, but he hopes to eventually work in his chosen field, Imaging and Photographic Science.